

THE DIESEL ENGINE

An insight into the workings of the modern diesel engine

Dr Rudolph Diesel would hardly recognise a modern diesel engine when compared with the one he unveiled to the world back in 1892. Over the years, many people have criticised its noisy operation, smelly fuel, billowing black smoke and poor performance. But sophisticated electronics and major advancements in induction technology have made this one-time lorry-only engine into an efficient and powerful power plant, which can move big motorhomes gracefully and economically.

Although the diesel has become the engine of choice for a large number of motorhomes, particularly pushers, many owners do not know how they work. In reality the diesel engine operates on very simple mechanical principles, and, with a little education, it's easy to understand how they work

The Basics

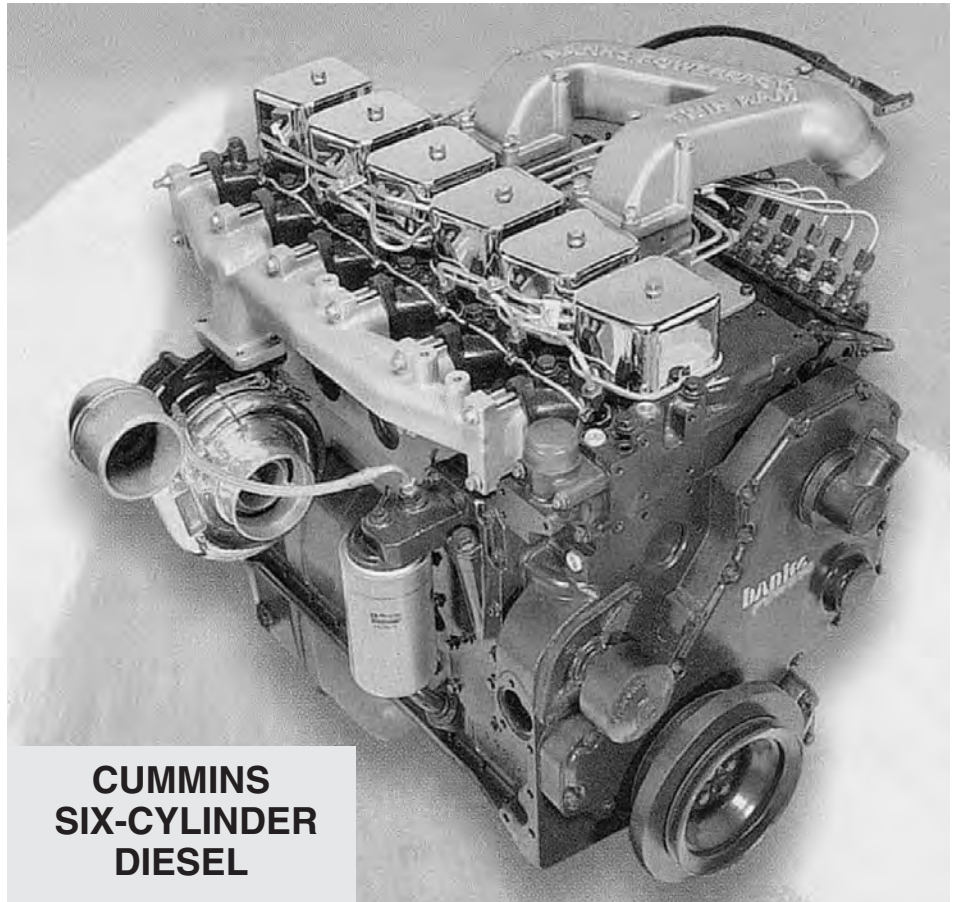
When the piston moves down in the cylinder it causes air to be drawn in through the engine's induction system. This air is then compressed, when the piston moves upwards, to a ratio of around 20 to 24 parts to 1. As a result air temperatures rise to about 1600 degrees Fahrenheit. Near the end of the compression stroke, fuel is injected into the cylinder through a nozzle and is ignited spontaneously as soon as it contacts the hot air. No electrical ignition is needed - a true 'plus' for the diesel. This illustrates why a diesel is called a 'compression-ignition' engine. Varying the amount of fuel injected into the cylinders controls the amount of power produced. Because it has a higher air-to-fuel ratio, a higher compression ratio and a higher heat value, a diesel is 25 to 30 per cent more efficient than a petrol engine.

Air-fuel Ratio

This is the amount of air in relation to fuel that enters the engine's cylinders for combustion. Typically a petrol engine has a ratio of 18:1, meaning there are 18 parts of air to one part of petrol by weight in the mixture. A diesel has a variable ratio of 100:1 at idle to 20:1 at full load. Pressures as great as 500 psi are reached in a diesel engine. The higher the compression ratio, the more power can be gained from a given amount of fuel. The higher compression ratio allows the engine to turn more of the heat energy of the fuel into mechanical energy.

Heat Value

Another reason for the greater fuel efficiency of the diesel engine is the heat



**CUMMINS
SIX-CYLINDER
DIESEL**

value of its fuel. It provides more heat per unit, so less fuel is needed to give the same power output. The heat value for diesel fuel is approximately 139,500 BTU (11 per cent higher than petrol).

Reliability and Durability

Diesel engines do not require an ignition system or a pollution-control device, so they usually operate more reliably than a petrol engine over longer periods of time. To handle their higher compression ratios, diesels are built to be robust. This emphasis on engine block strength has led to an engine that's very durable and operates for long periods of time. Many engines run well over 500,000 miles or more before having to be overhauled.

Other Diesel Advantages

Today's diesel engine produces lower overall levels of hydrocarbons (HC), oxides of nitrogen (NOx) and carbon monoxide (CO), thanks to the modern computer-controlled, direct-injection induction systems.

So, what do we know about those Old' Smoky Diesels?

Excessive Smoke from a diesel exhaust usually indicates the need for maintenance. When a diesel engine has warmed up to working temperature, there should be little, if any, significant smoke - black or white - coming out of the exhaust pipe. Black smoke indicates incomplete combustion, typically from dirty air cleaner, incorrect injection

timing, engine overloading or abnormally high intake-air temperature.

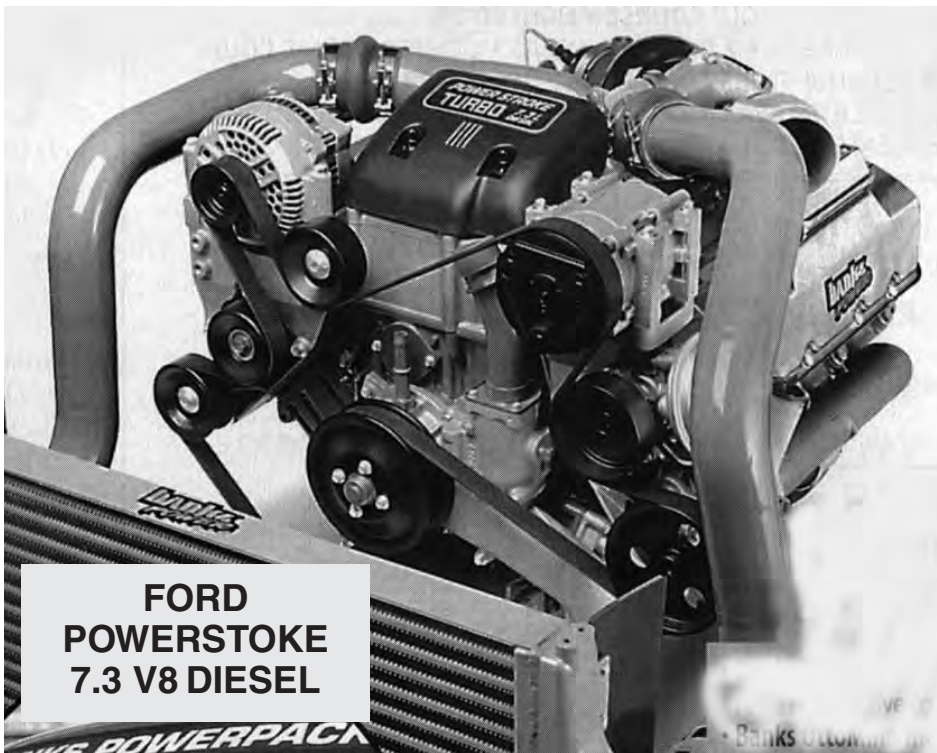
Diesel Disadvantages

The heavier weight and slower rpm of the diesel engine generally suggests a lower power-to-weight output than a similar petrol engine. However, the torque-to-horsepower ratio is usually higher, which is what really matters. An engine with high torque output can pull heavier loads with less effort (which is why the modern truck is diesel-powered). Most modern diesel engines are turbo charged and this more than makes up for lower horsepower output.

Diesels can be harder to start than petrol engines in colder temperatures. For reliable starting the diesel needs larger, heavy duty, batteries for more reserve power because the starter is turning over an engine with a 20:1 compression ratio. Indirect injection diesels, such as the Chevy 6.5, has glow plugs which pre-warms the fuel-air mixture in the combustion chambers of a cold engines. The glow plugs draw additional power from the batteries and so it is very important to keep your starting batteries in good condition and well charged.

And what about that Noise?

True, the diesel is noisy because of its combustion process. The unmistakable clatter occurs because of ignition delay. This is the difference in time between the injection of fuel into the combustion chamber and the fuel's ignition; the air-



content. It is this paraffin that provides the higher heat value. Switching to a low temperature diesel or using a fuel additive is recommended when operating in ambient temperatures of about 40 degrees Fahrenheit (5 degrees Centigrade) or colder. Many fuel distributors offer 'winter' grades at the pump, so blending should not be a concern for motorhome owners.

Don't ever try adding petrol to diesel fuel for use as a winter blend. Petrol won't affect the cloud point unless you add 30 or 40 per cent to your tank capacity. Also, petrol blending reduces viscosity, lubricity, cetane, flash point, and stability and, worst of all, it creates a very explosive atmosphere in the fuel tank.

Some engines, such as Cummins, have an engine block heater installed, which maintains some amount of heat in the engine whilst parked up in a cold climate. Some vehicles even have battery heaters as well. There are additives on the market that modify the formation of wax crystals, so the chilled fuel is allowed to flow. For the long haul, diesel-fuel heaters are recommended for use in fuel filter/water separators and to heat fuel lines and tanks. Various configurations are available.

When diesel fuel is injected into the cylinder it must be able to vapourise into a gas rapidly. The ability to ignite without a spark is called ignition quality and is measured using a cetane index. (A low cetane rating will cause difficulty in engine starting, hard engine knocking and a noticeable loss of power output).

Ignition quality affects engine performance; therefore the proper cetane number is essential for optimum operation, as well as lowering the self-ignition temperature. This is the temperature at which the fuel will begin to burn from the heat of compression in the cylinder. You should not confuse self-ignition temperature with flash point. Flash point is the lowest temperature at which fuel will ignite from a flame.

These fuels also vary in their volatility, which is how easily they are converted from a liquid to a vapour. Petrol is basically transparent and has a strong odour. That odour results from its vapour, and it is very volatile (low flash point). If a spark or flame were passed over the top of the jar, containing petrol, it would ignite the vapour immediately and explosively.

Diesel fuel has a golden hue. It is also somewhat transparent, but has little odour and virtually no flammable vapour to ignite. Hence, diesel fuel is safer to handle. Its non-flammable vapour creates pressure in the fuel tank and helps keep air and water condensation from entering the tank.

Water Contamination

In the US diesel fuel can contain up to 0.1 per cent water and sediment by volume according to their fuel specifications. For the diesel engine, this is not good news because the fuel system is prone to additional water contamination through the natural process of condensation.

Diesel Fuel

Obviously diesel fuel is the critical component of the diesel engine. Whenever a barrel of crude oil is processed, many types of petroleum products are made. To visualise the basic fuel oil grades only, let's compare them in an imaginary vertical scale. At the top of this scale is highly refined petrol, and at the bottom is a heavy fuel oil. In the middle, there are numerous diesel fuel/oils. Low cost diesel contains more contaminants, such as water and fine sediment that remain in the final product. These lower-cost grades are suitable for industrial diesels because they have been designed to run on them. Most high-speed diesels use fuels, which are adjusted to suit the climate the engines operate in. Many fuel suppliers provide one fuel for summer and another for winter.

You may wonder if diesel, being a 'middle' distillate, is cheaper to refine than petrol, and, if so, why it sometimes costs more? The truth is, it takes more crude oil to make a gallon of petrol than it does for diesel, and so diesel should be cheaper at the pumps. However because of distribution costs, rates of tax and other variables diesel is very seldom cheaper than petrol in the UK and if it is the difference is small. Also, the refineries would lose money every time they sacrificed a barrel of crude to make cheaper diesel fuel instead of a more profitable gasoline.

Fuel Pros and Cons

Fuels can be compared by their heat value, and diesel fuel has a higher heat value than petrol. Diesel also has a low viscosity index, meaning it thins when heated and thickens when cooled. Some diesel fuel, if exposed to temperatures of about 10 degrees or less, becomes cloudy. If chilled further, it will refuse to flow which is due to the paraffin (wax)

fuel mixing takes a minimum of 0.001-0.002 second. This time lapse or pause, called ignition delay, is at its greatest, noise-wise, with a cold engine or while under light load. The longer the delay, the greater the volume of fuel entering the combustion chamber and igniting violently. Hence, more engine 'clatter'. Continuing improvements in fuel-injection induction systems and the use of modern electronics are reducing diesel clatter to much lower levels.

The Higher Cost of a Diesel

Compared to a petrol engine of the same size, a diesel engine costs more initially. But it's made from stronger materials and precision-fitting components. This initial increased cost can usually be recovered within the first 50,000 miles of use due to its better fuel economy.

Diesel Lubrication and Maintenance

Diesel engine owners should only use engine oil that is designed specifically for diesels. Petrol engine lubrication oil should not be used. Engine oil is a story in itself, but if you're not sure you should refer to the engine handbook or contact the engine manufacturer for their recommendations.

The savings in fuel cost can easily pay for the cost of rebuilding a diesel engine at the end of its respectable service life (compared to a petrol engine).

A diesel should have more frequent oil and filter changes because of the chemical contaminants (such as sulphur) that get in the oil and fuel filters. The water-separator should also be serviced regularly. For all engines, it is important to ensure the air cleaner is kept in top condition. Keep a close eye on these elements, and clean or replace any that have damaged or deteriorated rubber seals.

Condensation occurs when warm air condenses on the cool walls of the fuel tank. The more air space above the fuel in the tank will lead to more condensation. In a damp climate it pays to keep your fuel tank as full as possible, which will keep condensation down to a minimum.

The consequences of water in diesel fuel can be damaging because diesel fuel has a double-duty job of being a fuel and lubricating the injection system. Water also freezes when subjected to cold, providing a habitat for microbiological growth, and facilitates the formation of rust and fuel degradation.

What is a microbiological growth? Water is a heavier fluid than diesel fuel and therefore settles to the bottom of the fuel tank. At the point where water and diesel separate, airborne micro-organisms introduced through water condensation and poor fuel-handling practices settle and grow. They live in the water and feed on the hydrocarbons in the fuel. If the habitat is ideal, they can double their population every 20 minutes! If left to them, the colony could grow so large as to completely contaminate the fuel tank, foul the fuel gauge sender and quickly plug the fuel filter. Micro-organisms also produce waste acids that attack metal surfaces, resulting in loose particles of iron oxide.

Diesel can be protected by the use of a biocide additive. Biocides are basically pesticides that kill the bacteria in its home environment. Be prepared to change filters often when treating a contaminated fuel tank, because the dead microbes will eventually fall into the fuel stream.

Today, there are many quality fuel additives on the market to kill microbes, lower fuel cold-flow characteristics, clean injectors and stabilise stored fuel. Water-dispersing additives can be used but they tend to reduce the performance of fuel-water separators, which are far more efficient at doing this important job than additives. Fuels leaving the refineries these days are already treated with certain additives so that the end product meets necessary criteria for use in internal combustion engines.

Solid Contamination

You may have heard the term 'light sweet crude' and wondered what it means? This refers to the sulphur content in crude oil. Some crudes contain more than 1.0 per cent of sulphur and smell like rotten eggs, while crudes generally containing less will have a pleasant sweet smell. High amounts of sulphur in oils are corrosive to refining equipment and later, when burned, are recognised as air pollutants. Conversely, too little sulphur content is also bad. There is speculation that low-sulphur diesel fuel causes injection-system O-rings to shrink, harden and allow fuel leaks. Also, sulphur acts as a natural anti-oxidant. It is the oxidation of the fuel that produces gums and tars, otherwise known as asphaltene.

Diesel fuel, like petrol, is prone to solids contamination. However, the fuel filter should be able to rise to the task. Solids will eventually plug the filter element, creating higher fuel-flow resistance or restriction. As the filter catches more contaminants, the engine will noticeably lose power. Indications include: hard starting, excessive black smoke and reduced power. Standard-equipment filters are generally fitted to catch the large contaminants in the 10- to 40-micron size, which are invisible to the eye. It pays to change your filter(s) regularly on a calendar rather than mileage basis. It is also well worthwhile having spare filters on your vehicle at all times.

For the best diesel-fuel system protection, the addition of a fuel filter/water separator is a good investment. A fuel filter/water separator can protect the system from water and solid contamination with minimal maintenance. Newer diesels have them located near the tank. Water and solid contaminants are filtered before the fuel reaches the engine. Many units have transparent collection bowls or may be fitted with electronic water detectors, to easily monitor water collection.

Of the units on the market, Racor makes the one most popular with motorhome owners. Many diesel-coach



RACOR FUEL FILTER

builders such as Blue Bird, Foretravel, Monaco and Safari (to name a few), will include internal tank fuel heaters as original equipment if required.

Storage & Stability

Over time, all fuels will become unstable and begin to oxidize. Because diesel is a middle distillate and is not as highly refined as petrol, it tends to have a shorter shelf life. If you plan to park your motorhome for more than three months, a diesel-fuel stabiliser additive is recommended to maintain fuel quality and resist oxidation. Add the stabiliser and then top off the tank(s) before storage.

Conclusion

Now you have a bit more insight into diesel engines you should be in a better position to make a decision as to which engine best suits your needs. If you already have a motorhome powered by a diesel you should be armed with some information on how to maintain it at its peak performance at all times. Some owners still prefer a petrol engine but I'll stay with the good old turbo diesel.



CUMMINS ENGINE IN A PUSHER MOTORHOME

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